

## Retrofit of Existing Residential Building: a Case Study

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**Abstract:** There are about 42 billion square meters of existing buildings in China. The energy efficiency of existing buildings directly relates to the energy consumption of the building sector. The retrofit of existing residential building began in the 1990s in Heilongjiang. The Sino-Canada demonstration project and Sino-France demonstration project of retrofitting existing residential buildings were carried out in 1997 and 2004, respectively. The retrofit method and energy conservation potential of the envelope and heating system of northern existing buildings are analyzed in this paper, combining the experiences of retrofitting existing residential buildings in Heilongjiang. The software was compiled to aid the design of the envelope retrofit in Heilongjiang and to analyze the working situation in existing residential building heating systems. The imbalance of the indoor temperature and the quantity of heating loss from opening the window in different retrofit projects are presented. The emphasis on energy efficiency retrofit of the envelope of existing residential buildings should be placed on the wall in northern region. It is possible to reduce about 50 percent of energy consumption of buildings by insulating the wall. The external insulation is suitable for retrofitting existing buildings, and the moisture transfer should be considered at the same time. To insure actual reduction in energy consumption, the heating system should be retrofitted when the envelope is insulated.

**Key words:** existing building, energy efficiency retrofit, envelope, heating system

### 1 INTRODUCTION

The 420 billion square meters existing buildings

in China are high energy consumption buildings. The retrofit of existing building directly relates the energy efficiency and sustainable development. Realizing the retrofit of existing buildings, avoiding energy and resource waste and improving the thermal comfort of buildings are important problems to be solved immediately in our country. As the energy efficiency of buildings booming, residence system's innovating and the innovation proposal of heating system in north China begin to perform, the problem of existing buildings retrofit will become outstanding and great task.

The retrofit of existing buildings in Heilongjiang province began in 1990. The scientific research project, the *Energy efficient measures of external wall of existing building retrofit* was the first demonstration project. The Sino-Canada demonstration project of existing residential building retrofit in Harbin were carried out in 1996~1999. The project of Heilongjiang province, *Energy efficient retrofits of existing building in Daxing'anling* were finished in 2003. The Sino-France demonstration project of retrofit existing residential building is carried out now. After yeas of practice and demonstration, the experience were accumulated in the existing buildings retrofit field, and the retrofit methods were maturing gradually. Because the retrofit of heating system was hard to be realized, in the accomplished projects, only the Sino-Canada project realized all-around existing heating system retrofit. Summarizing and using the experience of retrofit projects, the software which could analyses the retrofit proposal of envelops and the software

which could analyses the condition of heating system after envelop retrofit were developed according to the national criterions and region standards.

## 2 ENERGY EFFICIENT RETROFIT OF ENVELOPS

In China, the envelopes almost wasn't insulated before 1980 and the thermal properties of existing building's envelop weren't good enough. So insulation is an important method of retrofit. As usual, insulation of external wall and roof are preferential measures of such many measures that improving the thermal properties of envelopes.

The construction technology of external insulation is difficult. It should have the performances of quake-proofing, wind-proofing, fire protecting, waterproof, air permeability, and durability also. The external insulation wall should prevent condensation of moisture. Especially, the material of exterior finishing should not be affected by the climate. There are several types of external insulation wall systems nowadays. The EPS external insulation system is the most suitable system which can be applied in the envelop retrofit of existing building.

### 2.1 Energy Efficient Measures of External Wall of Existing Building Retrofit

From 1990 to 1992, the scientific research project that *Energy efficient measures of external wall of existing building retrofit* had done by the former Harbin University of Civil Engineering and Architecture. The project aimed at the energy efficient retrofit of the external wall of existing building with rock wool and developed steel fiber reinforced concrete board and its fixed technology on external wall. The aim of the project was saving heating energy consumption of 30% because the new building in heating region should fit the design standard of energy efficient 30% in 1990.

The demonstration building located at the residential buildings region of Heilongjiang building design institute in Harbin. It was completed in 1979. The building was brick and concrete construction, five floors, southeast and the building area was 1723 m<sup>2</sup>. Although the layout of building structure was

reasonable, the construction quality was not good. The air leak from the circumference of window was serious and some inner surface of external walls formed condensation of moisture.

Before retrofit, the annual heating energy consumption was  $9.28 \times 10^8$  kJ. The annual coal consumption for heating was 31.68 tons standard coal. After retrofit, the annual heat consumption was  $6.73 \times 10^8$  kJ. The annual coal consumption for heating was 22.97 tons standard coal. With the  $2.55 \times 10^8$  kJ reduction of the annual heating energy consumption and 8.7 tons standard coal reduction of the annual coal consumption for heating, the energy efficient rate was 27.48%. From the reduction we could know that the energy efficient quantity of rock wool insulation board to the retrofit was considerable.

### 2.2 The Sino-Canada Retrofit Demonstration Project of Existing Building in Harbin

The energy efficient retrofit project of existing building of Harbin, i.e. the Sino-Canada demonstration project of energy efficiency cooperation was a sub-project of "the ninth five years" key scientific and technological project of the State Planning Commission. The project accomplished by Harbin Wall retrofit and Building Energy Efficiency Office, former Harbin University of Civil Engineering and Architecture and Harbin Institute of Coal Design and Research. An employee residential building of Harbin Institute of Coal Design and Research was selected as the demonstration building. According to the demand of the project and refer to the *Energy conservation design standard for new heating residential building (JGJ26-95)*, the retrofit would realize 50% energy efficiency. The project not only accomplished the retrofit of envelop and heating system, but also do the research on the economic analysis, method and police of raise funds and etc. It was a synthetically retrofit project of existing building.

The project was constructed in 1983, brick and concrete construction, 7 floors, 490mm bricks walls and inner cement, double wood windows, closed balcony and 120mm cement and perlite insulation roof. The area of building was 2442 m<sup>2</sup>. There were 2 units and 42 apartments.

Firstly, combining test results and calculation analysis, the existing building energy consumption was analyzed. Secondly, the heat consumption of each envelop were decomposed and the corresponding energy efficient potential could be acquired. After the energy efficient objects were ascertained, the retrofit proposal could be decided. Finally, to retrofit the building under the proposals, analyze the energy consumption and the retrofit results from the view point of energy consumption, economy and technology.

The demonstration project took measures as following to realize the energy efficient retrofit:

- . External wall: 50mm polystyrene board external insulation;
- . Roof: 100mm polystyrene board insulation and inverted roof;
- . Window: keep the original wood window;
- . Thermal bridge: to insulate the thermal bridge between the two layers of the double wood window;
- . Staircase: to add porch, change the door to double door and heating.

The index of heat loss of building was 30.99 W/m<sup>2</sup> before retrofit, and it was 20.05 W/m<sup>2</sup> after retrofit. The energy efficient rate was 35.3%. This retrofit already satisfied the demand of 50% energy efficiency.

### 2.3 Energy Efficient Retrofits of Existing Building in Daxing'anling

The retrofit project was located in Jiagedaqi in north Heilongjiang. The building area of the retrofit project was 2098m<sup>2</sup>, 7 floors, 2 units and 72 apartments. The envelops were as followings: 490mm brick external wall, cement mortar finishing; closed balcony; PVC window (double window in the north; Single-frame and Double-glazing Window in the south and northern window inside balcony) and 150mm perlite insulation roof. The indoor temperature was low before retrofit and the inner surface of external wall were moldy and condensation.

Restricted by the various conditions, the proposal was ascertained as followings: insulated with 100mm polystyrene board to external wall,

30mm to the inter wall of staircases on the first floor and thermal bridges; added door at the entrance of the staircase; changed the metal-electronic intercom door to double door and added porch.

Calculated the energy consumption, the index of heat loss of building was 40.59 W/m<sup>2</sup> before retrofit and 24.77 W/m<sup>2</sup> after retrofit. The energy efficient rate was 39.5% and the energy efficiency rate of external wall was 50%.

### 2.4 Summarization and Analysis of the Three Retrofit Cases

Summarizing the retrofit experience of the existing building in Heilongjiang province, according to the results of the energy consumption analysis, it could be shown that the energy consumption proportion of transfer heat losses of external walls, windows, roofs and staircases and heat losses of infiltration were bigger than the heat losses of others'. The windows retrofit should take the actual situation of the building into consideration and the proposal should be selected economically, practicably and reasonably, so the primary retrofit envelops of proposal should be put onto the external walls. The building energy efficient rate using external wall insulation could be more than 50%. The retrofit of external wall should employ external thermal system. To ascertain the retrofit measures of the wall, it should take energy efficient rate, heat transfer and moist transfer into account synthetically. Using external thermal system, the insulation thickness should be considered according as followings:

- . Satisfy the demand of energy-efficient ratio.
- II. Solve the durability problem of sticking: The temperature of the sticking between the insulation and the base wall must be above freezing point.
- . The thickness of the insulation should be the bigger one of the above two calculation results.
- . Check the moisture-resistant to satisfy the thermal design demands of envelops.

Basing on the practice of retrofit projects in the past 10 years, the *Existing Building Energy-efficient Retrofit Proposal Analysis Software* was developed and it could calculate energy losses and ascertain reasonable, economical, proper and applicable retrofit proposal which summarized from the existing

experiences for different regions in Heilongjiang province whose climate conditions and index of building heat loss were different. In the retrofit project of DaXingAnLing, the energy consumption before and after retrofit and the insulation proposal of external wall were calculated applying this software.

### 3. ENERGY EFFICIENT RETROFIT OF HEATING SYSTEM

Because the retrofit of heating system was hard to be realized, only the Sino-Canada project realized all-around existing heating system retrofit in the accomplished project.

In this project, a loop of original heating system was replaced by vertical single-pipe cross-over heating system. Two types were taken to adjust the indoor temperature, one was placing thermostat in the entrance of the radiator, and the other was placing regulating locking tee valve at the entrance of the radiator and placing constant temperature valve in the bottom room of each vertical pipe. To direct heating system design of the new building, another loop of the original heating system was replaced by double-pipe horizontal heating system.

Two types were taken to control the indoor temperature. One was placing electromagnetic valve at the entrance of every group of radiator, and equipping an indoor temperature controller in every room. The other was placing an electromagnetic valve in every horizontal loop and an indoor temperature controller in every room which was equipped with electromagnetic valve, and setting a manual control valve in the entrance of every group of radiator. After retrofit, the two loops of heating system were all adjustable and measurable and the indoor temperature was uniform.

Using the developed software *Heating System Working Conditions Analysis Software for Existing Buildings*, the three projects mentioned above were calculated, and the indoor temperature of retrofitted envelop was simulated and analyzed.

The reduction scales of the design heating load of each room were different after energy efficient retrofit. The effect factors were not only the insulation performance of envelops before and after

retrofit but also the detail of the construction of envelop. The reduction scale of the design heating load in a room of the same floor was affected by the sum of external walls, and the reduction scale of the heating load in a room corresponding to a vertical pipe was affected by its position as bottom floor, middle floor or top floor.

The distribution of indoor temperature of the retrofitted buildings was affected by the reduction ratio of the design heating load, the more reduce ratio was, the higher the indoor temperature was. So the average temperature in the room with two external walls was higher than in the room with one external wall. The indoor temperature in the top floor was higher than in the middle floor or bottom floor if insulation was realize in the roof.

The dweller might open the windows to release heat if the indoor temperature was too high. At this time, the temperature in the room would fall and the thermal comfort would improve. But the quantity of the released heat was not allowed to ignore. This phenomenon was general in the Sino-Canada demonstration project, but was rare in the project Energy efficient measures of external wall of existing building retrofit.

Although the indoor temperature was usually higher than 18℃, it was usual to convert the real heat consumption of the retrofitted envelop to the heat consumption which indoor temperature was 18℃ in order to calculate the energy efficiency ratio. Actually, the heat consumption of retrofitted building was higher than the calculated value and the excessive heat might be used to improve the indoor thermal comfort.

The distribution of indoor temperature of each project were quite different after retrofit, because each energy-efficient project had the different retrofit proposal of envelop and different insulation capability and seal conditions of original envelop. In the energy efficient retrofit of heating system we should take all actual facts into consideration instead of taking a same measure. If it was difficult to realize the temperature control retrofit to the building's with vertical single-pipe system, different adjustment or retrofit proposal might be considered against the actually distribution of indoor temperature.

#### 4 CONCLUSIONS

The energy efficiency of existing building is important to our country. It must develop from demonstration project to popularization. In the process of retrofit, the retrofit focus should be the external wall and the building energy efficient rate would be more than 50%. It should be noticed that the retrofit should be realized both to envelopes and heating system together to fulfill the purpose of energy efficiency really. This is because that the heating quantity would not change as the heating system had no retrofit. Then the indoor temperature of buildings would rise. The residents' behaviors of opening windows to release heat causes great heat waste. Further study on how to solve the above problems should be carried out. The energy efficient

retrofit research method of Heilongjiang province and the soft wares in this thesis can be an assistant to retrofit in north China.

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